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TEMPERATURE PROFILES OF AIR TRANSPORTED MATERIAL (U)

by
H. C. Schafer
and
R. A. Dickus
Propulsion Development Department

ABSTRACT. Winter flights of MAC aircraft were instrumented to determine the temperatures and temperature profiles to be expected in material during air transport. Flights in 21st Air Force C-141, C-124, and C-133 aircraft from the United States to Greenland and Europe during January are reported herein.

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

M. R. Etheridge, CAPT, USN . . . . . Commander

H. G. Wilson . . . . . Technical Director

FOREWORD

This final report covers work conducted during the winter of 1968-69 to determine typical cold weather temperatures experienced by air transported ordnance.

The work was performed under Work Request WR 1-6025 in support of AIRTASK F19.332.301.

This report has been reviewed for technical accuracy by Warren W. Oshel.

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CONTENTS

INTRODUCTION

Due to the controversy which presently exists over predictions of temperature profiles for air-transported materials, the Quality Assurance Division at the Naval Weapons Center (NWC), China Lake, Calif., was assigned the task of measuring maximum and minimum material temperatures during actual air transportation conditions. The purpose was to provide empirical data which would serve as a basis for more accurate predictions.

It was decided to weigh the measurements as heavily as possible to the cold extreme during the normal routine flights of the Military Airlift Command (MAC).

A request was made to headquarters personnel at Scott Air Force Base, Illinois for NWC personnel to measure cargo temperatures on the most northern flights scheduled during the winter of 1968-69. It was learned that they had an Army-Air Force Readiness Exercise scheduled for the period when NWC personnel would be available. These twin exercises, "Reforger" and "Crested Cap", would require the 21st Air Force, McGuire Air Force Base, New Jersey, to make many flights between the United States and Northern and North Central Europe. It was indicated that flights would be on a catch as catch can basis. The Air Force extended full cooperation to NWC personnel to see that a representative assortment of flights was made available.

Figures 1, 2, and 3 are examples of the aircraft used in this measurement sequence. Figure 1 is indicative of the MAC transport aircraft presently in use that will be used in the future. The other two are used on less than a first line basis.

MEASUREMENT PROCEDURE

procedures used to measure cargo temperatures on the in-service Air Force MAC cargo aircraft were such that the NWC test personnel would not disturb the 21st Air Force mission schedule in any way. The program was arranged with MAC Headquarters so that the greatest share of the work load would be Navy responsibility. The NWC personnel were assigned to the cargo aircraft by MAC, Air Command Post (ACP) as air crew members to fly with the NWC instrumentation during the particular mission. The flight engineer was requested to record indicated outside air temperature, altitude, speed and position obtained from cockpit instruments every 30 minutes throughout the flight. The conversion of indicated outside air temperature to true outside air temperature is given in Appendix A.

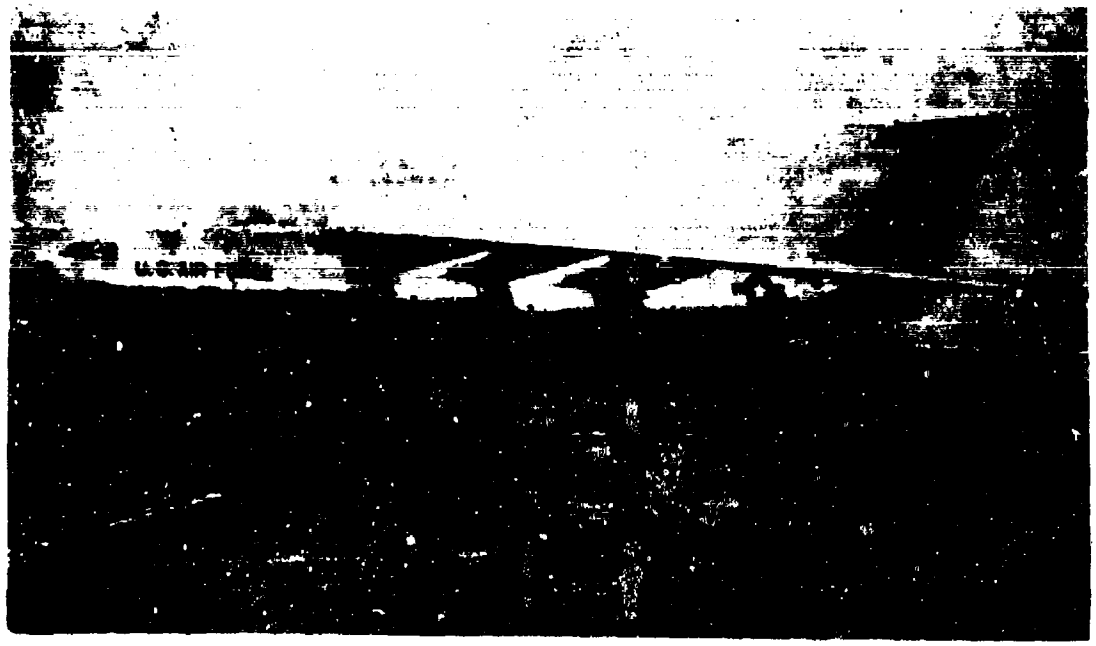

FIG. 1. C-141.

FIG. 2. C-133.

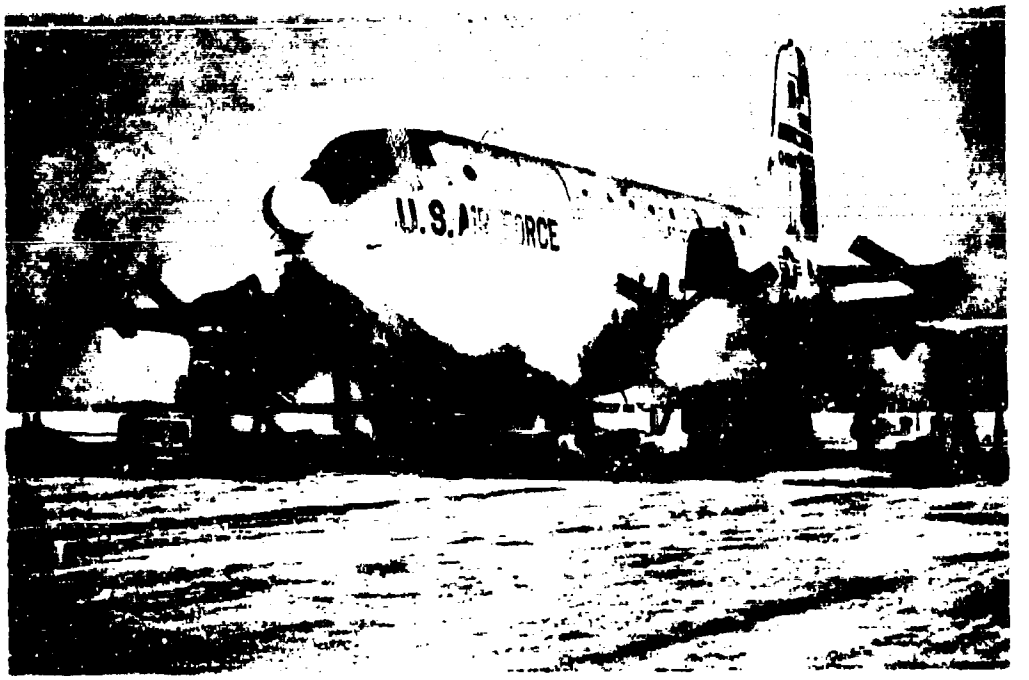

FIG. 3. C-124.

After the aircraft was loaded with cargo and ready for flight, the NWC personnel installed up to 12 thermocouple probes at various depths into the conglomeration of cargo so as to get a better idea of the thermal response of a cross section of that cargo. The probes were connected to the temperature recorder with the thermocouple extension wire. The temperature recorder periodically sampled the data during the entire time power was on the aircraft, both on the ground and during the flight.

The location of the thermocouple probes varied with each flight due to the change in cargo configuration requirements of each mission. The description of the cargo can be generalized as wooden crates, metal or cardboard boxes, or bulk filled sacks tied down to 88 x 108 inch metal pallets.

Figures 4 through 9 show the usual cargo configurations. Where possible, it was intended to send an unattended recorder on a flight between two bases where NWC technicians were located (i.e., McGuire AFB and Rein-Main, Germany). However, in actuality, only one flight turned out that way. The remainder were all accompanied.

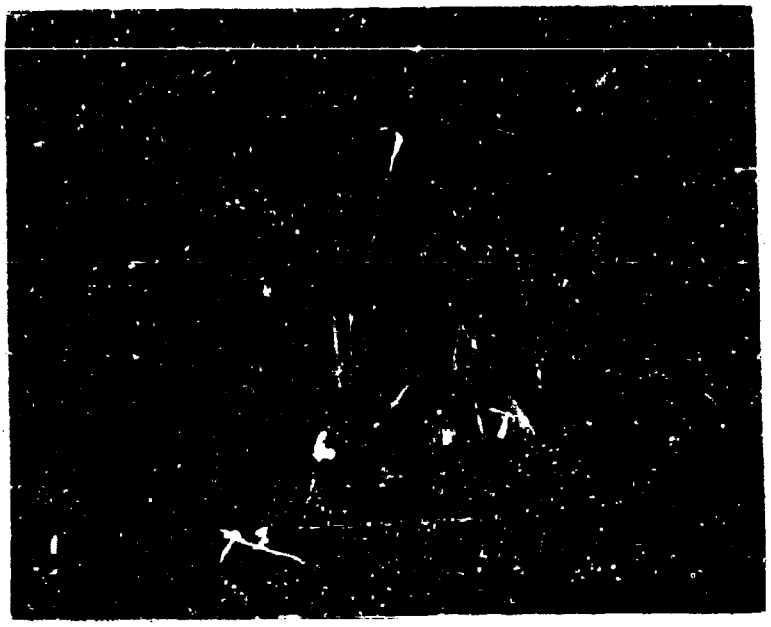

FIG. 4. Bullpup Missile Sections.

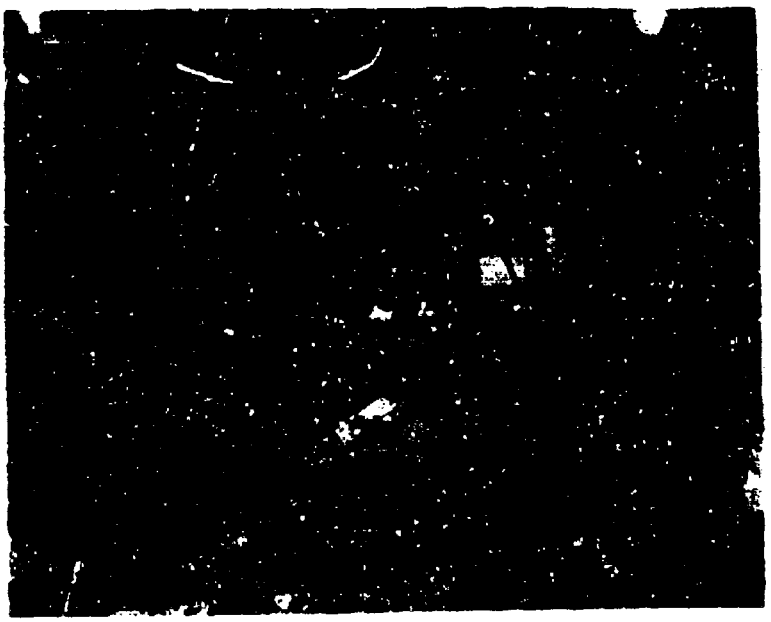

FIG. 5. General Bulk Cargo.

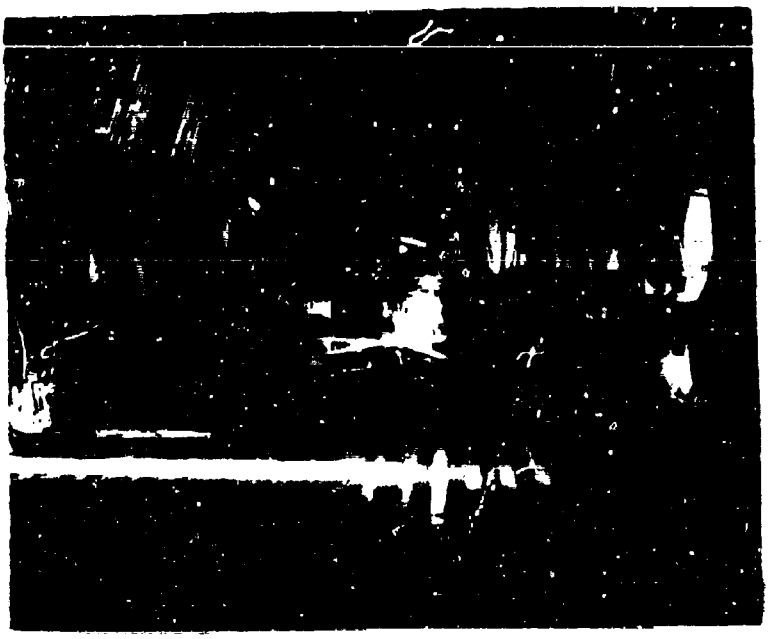

FIG. 6. Liquid Bulk Cargo.

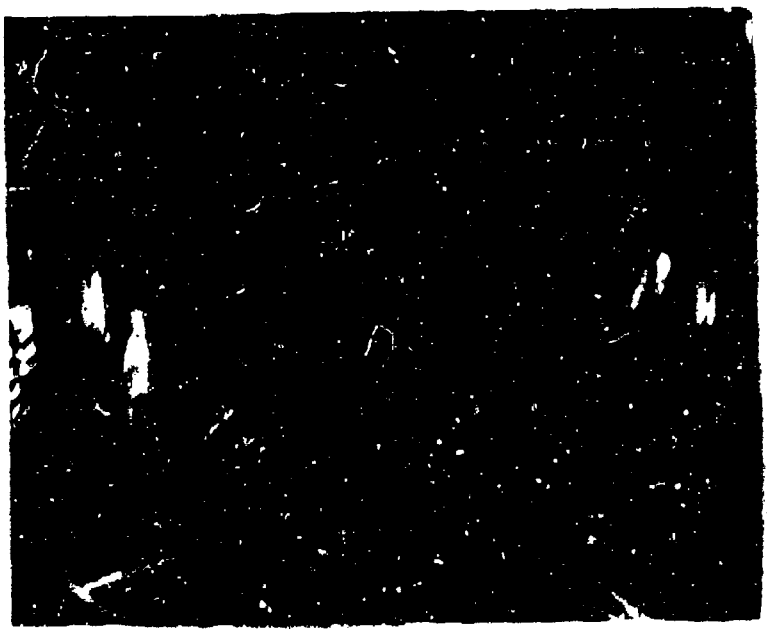

FIG. 7. Mixed Size Miscellaneous Cargo.

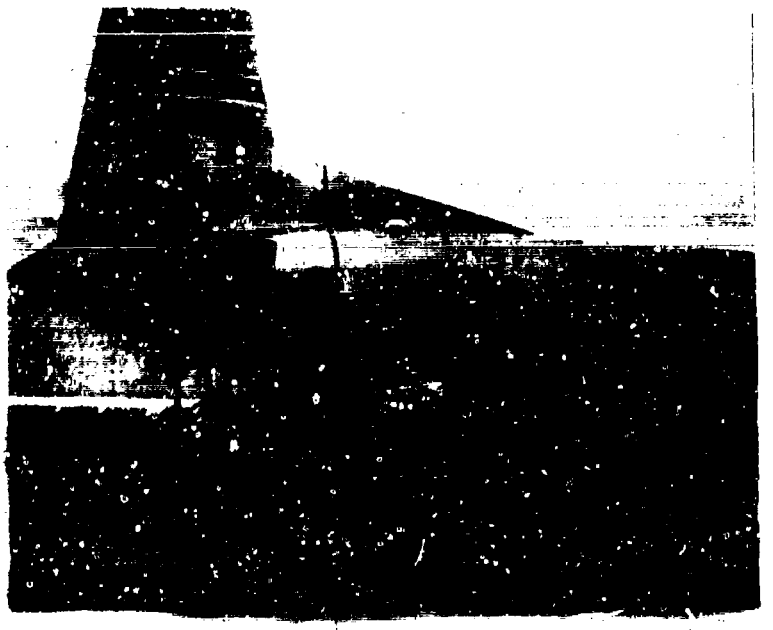

FIG. 8. Cargo on Pallets Awaiting Loading.

FIG. 9. Cargo Loader in Mating Position.

INSTRUMENTATION

The equipment, used to measure the cargo temperature during the flights, consisted of a 12 channel multipoint strip chart type recorder, temperature probes and copper-constantan thermocouple extension wire. The temperature probes were a copper-constantan bimetal type thermocouple element, ceramic insulated and encased in a 1/8-inch-diameter metal sheath giving the probe sufficient rigidity to penetrate the cargo bulk.

The recorder was a potentiometer type temperature measuring instrument converted and rebuilt at NWC. The basic instrument is comprised of parts from the Honeywell Model 15 and 16 instruments. The rearranging of the various parts, along with potting of electronic circuitry and conversion to aircraft power result in an instrument that has been successfully used in tactical missiles at velocities above Mach 2.0. The recorder environment on the transport type aircraft was extremely mild compared to the environmental parameters for the recorder design.

The recorder required a power source of 115 volt 60 cycle AC. Modifications including an ERA Transpac IT 2106 inverter were necessary to accommodate the variety of power sources that were conveniently accessible in the cargo compartment of the aircraft. The power sources available on the Air Force C-141, C-133, and C-124 aircraft were 115 VAC 400 cycle, 28 VAC 400 cycle, and 28 VDC. Adapting the recorder to accommodate the different power sources did not in any way degrade the operation or calibration of the measuring equipment, however, as per good measurement practice, the recorder calibration was checked before and after each flight as part of the routine.

The thermocouple extension cable was regular solid conductor copper-constantan 20 gauge lead wire. The insulation was polyvinyl chloride over each conductor. The bundle of six each was covered by a Faraday shield of aluminized Mylar which was grounded to the recorder. The shielded bundle was encased in another thick sheath of polyvinyl chloride. This combination could have given trouble, since it is well known that solid conductor wire will fatigue harden and break when exposed to aircraft vibration. Also, polyvinyl chloride will get hard and brittle at low temperatures. However, this cable was used because prior NWC experience when riding long distances in MAC cargo aircraft had indicated that the cargo compartment would not reach extreme low temperatures. Also, this cable is extremely resistant to rough handling as can be the case during loading and unloading of palletized and unpalletized cargo.

RESULTS

The cargo temperature data were accumulated on the MAC aircraft from 18 January 1968 to 1 September 1969. During that time, five complete aircraft round trip missions were flown with 13 separate flights or legs where the cargo was either off-loaded or on-loaded at each stop. Table 1 gives a brief flight log. Each leg of the mission may have had a different type of cargo such as boxes or crates on pallets, vehicles, missile motors in shipping containers, mail, aircraft engines, 55-gallon drums containing flamables, etc. During the five round trip missions a total of 93 hours, 55 minutes of flying time was logged, resulting in cargo temperature data on three different types of MAC aircraft. The aircraft used were the C-133, a relatively slow, medium altitude Turbojet aircraft flying at about 260 knots at altitudes of 17,000 to 20,000 feet. A piston-engine-powered C-124 provided data at lower altitudes of 8,000 to 11,000 feet and 200 knots. The C-141, the newest heavy cargo aircraft in the MAC squadrons, provided cargo temperatures for jet aircraft at high altitudes of 35,000 feet or more and speeds of 450 knots.

Figures 10 through 17 give a good idea as to the thermal exposure of general cargo during air transport. Figures 10, 11, and 12 are indicative of the C-141 induced situation while Fig. 13 and 14 show the C-133 and Fig. 15, 16, and 17 the C-124 situations. The shaded areas on the figures are the material temperature-envelopes measured. Notice in Fig. 10, 11, and 12 that the cargo space is held at nominal room temperature. Discussions with Air Force personnel disclosed that the chance of pressure loss, which is related to temperature in the C-141, is extremely remote if line service can be the basis for judgment. This relationship between pressure loss and temperature is discussed later. Only in three instances in the history of the C-141 flights were pressure losses reported. In each case, the regulation emergency procedure of crew going on pressure oxygen until the pilot could get the craft down to a lower altitude was carried out. This being the case the cargo was no longer exposed to the low temperatures of the nigh altitudes.

Figures 13 and 14 show that for reasons of fuel economy and the flight characteristics, the C-133 does not very often attain even the high altitudes specified in the flight manuals. Notice in Fig. 14, even on an over-ocean flight, the altitude averaged only 19,000 feet.

The low, slow Air Force Reserve C-124 situation is shown in Fig. 15, 16, and 17. Notice that the flight altitude for these situations is between 9,000 and 11,000 feet. This in itself will negate extremes of cold being imposed on the carried material.

Appendix B gives a complete log of flying data hours and a breakdown of the aircraft, its mission, and time in the air during each leg of the mission.

TABLE 1. Flight Log.

Aircraft	Flight S/N	Destination	Flight time	Total time
C-133	2010	McGuire to Argentia, Newfoundland	4 hr 50 min	
		Argentia to Prestwick, Scotland	6 hr	10 hr 50 min
C-124	10092	McGuire to Goose Bay, Labrador	6 hr 20 min	
		Goose Bay to Sonderstrom, Greenland	5 hr 35 min	
		Sonderstrom to Kulusuk, Greenland	2 hr 45 min	14 hr 40 min
	21036	McGuire to Goose Bay, Labrador	6 hr	
		Goose Bay to Rein-Main, Germany	12 hr 10 min	
		Rein-Main to Prestwick, Scotland	5 hr 30 min	
		Prestwick to Azores	7 hr 15 min	
		Azores to Dover	12 hr 15 min	43 hr 10 min
C-141	8083	McGuire to Rein-Main, Germany	6 hr 55 min	
		Rein-Main to McGuire	10 hr	16 hr 55 min
	40642	Rein-Main to McGuire	8 hr 20 min	8 hr 20 min
Total flying time				93 hr 55 min

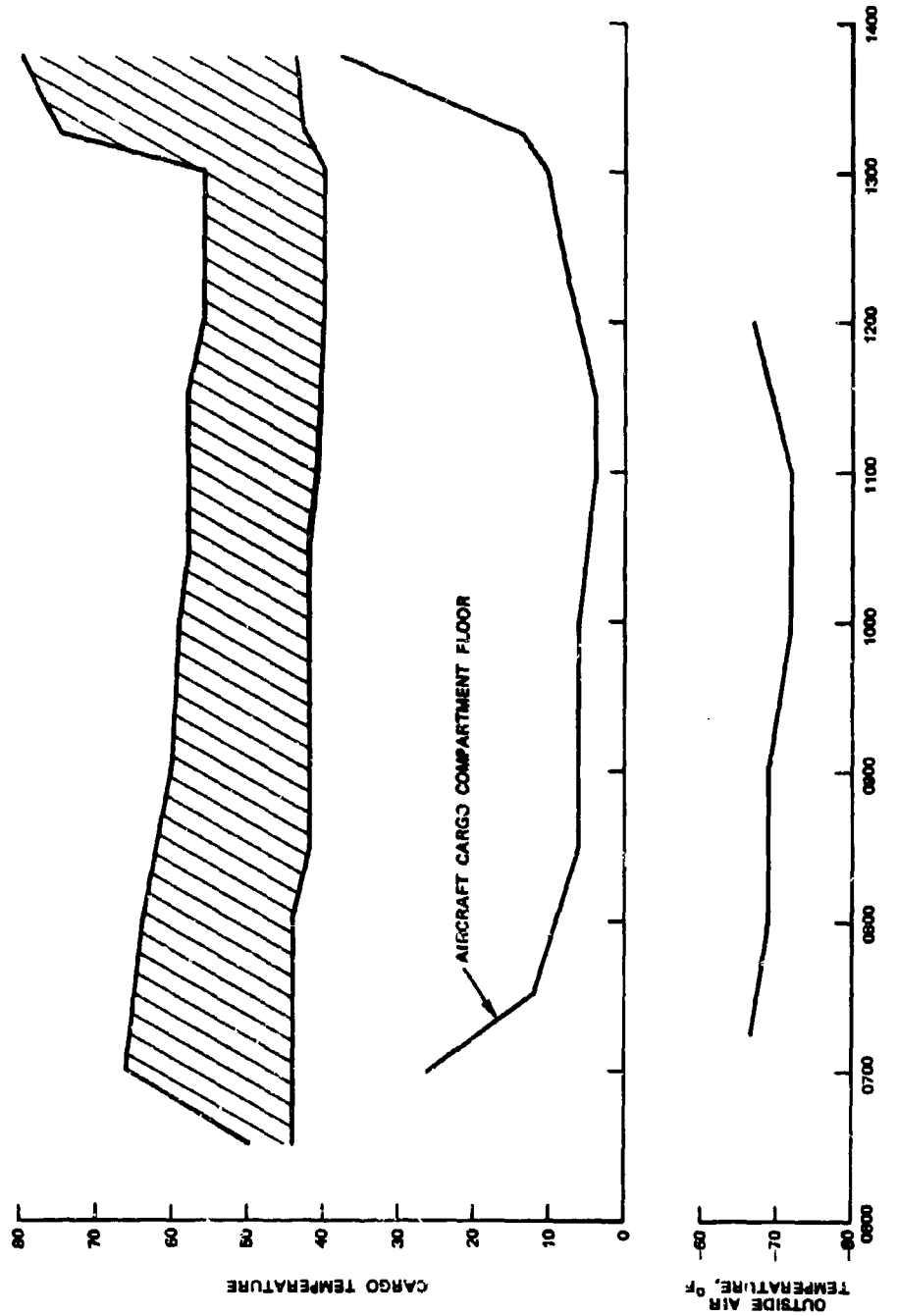

FIG 10. C-141 Flight 08083, McGuire AFB to Rein-Main, Germany (1/18/69).

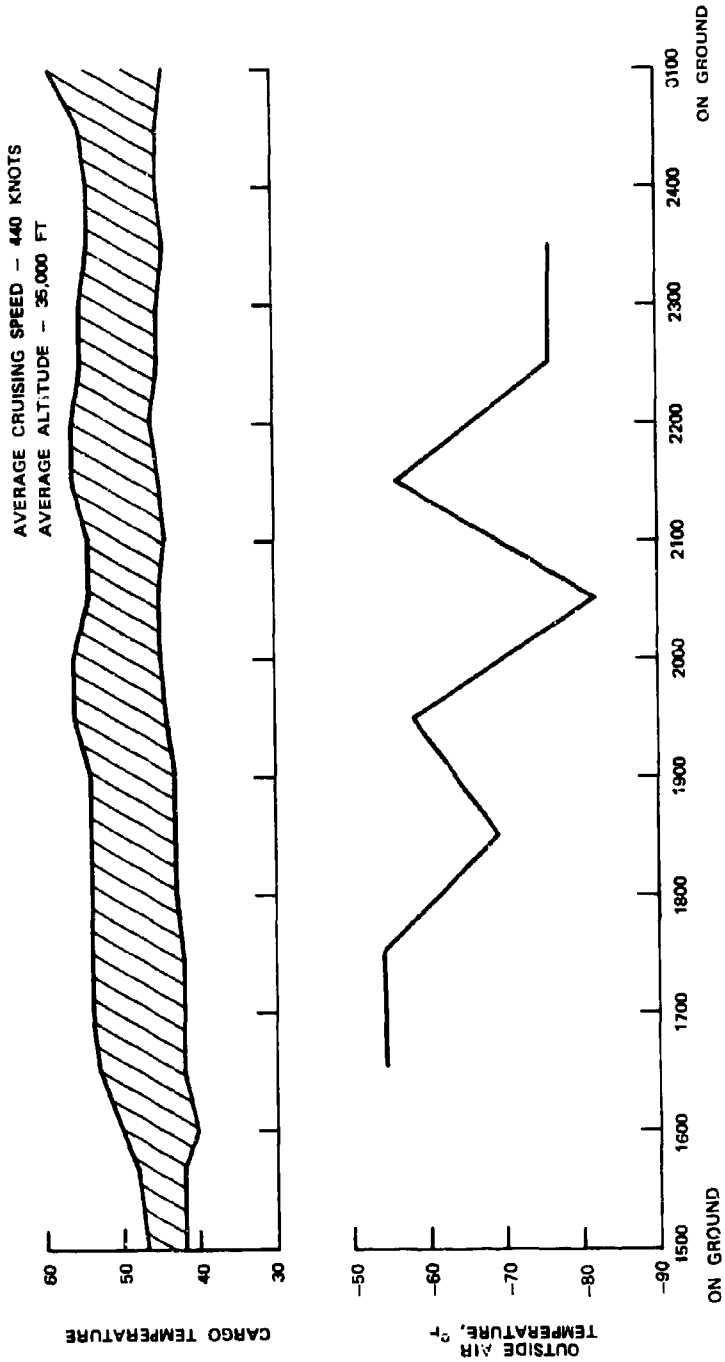

FIG. 11. C-141 Flight 08083, Rein-Main, Germany to McGuire AFB (1/18/69).

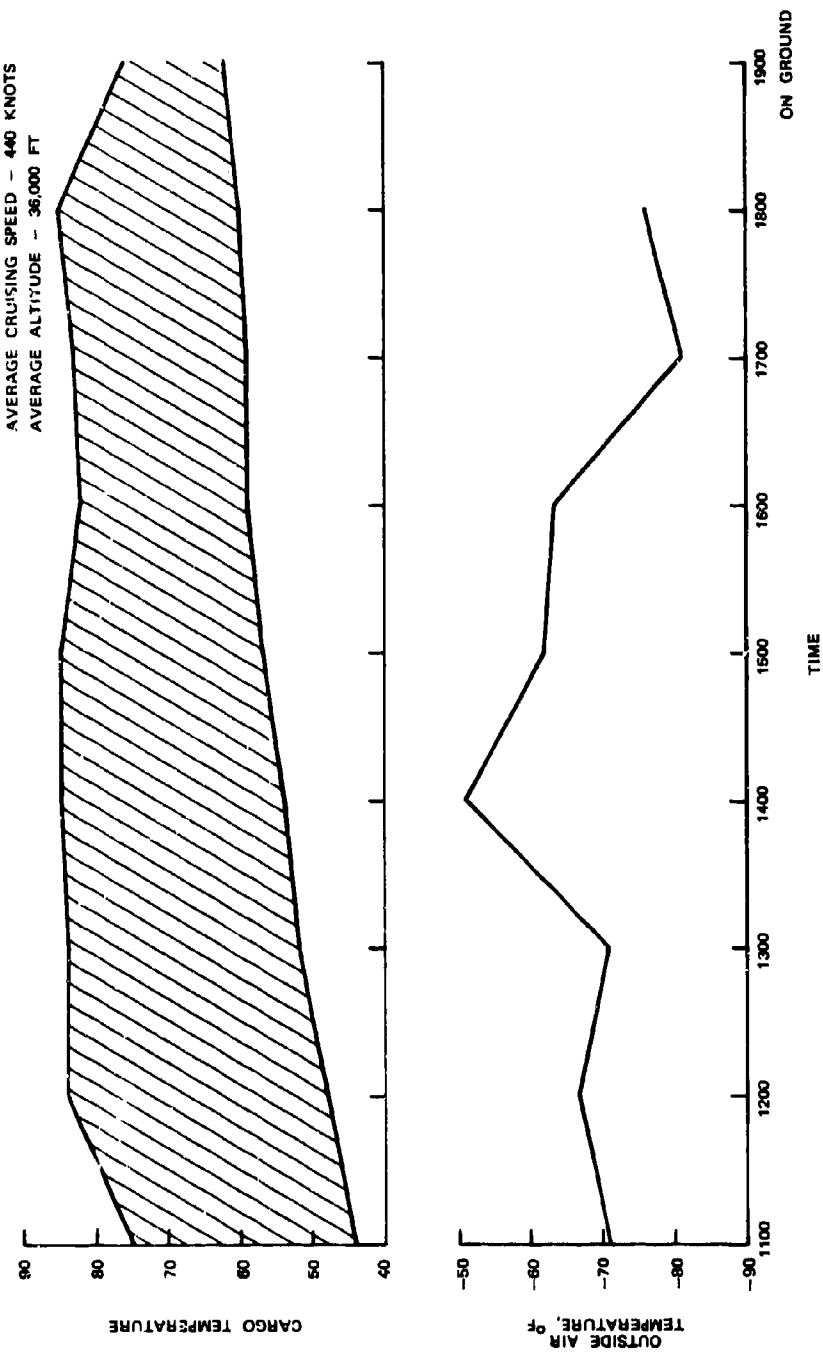

FIG. 12. C-141 Flight 40642: Rein-Main, Germany to McGuire AFB (1/22/69).

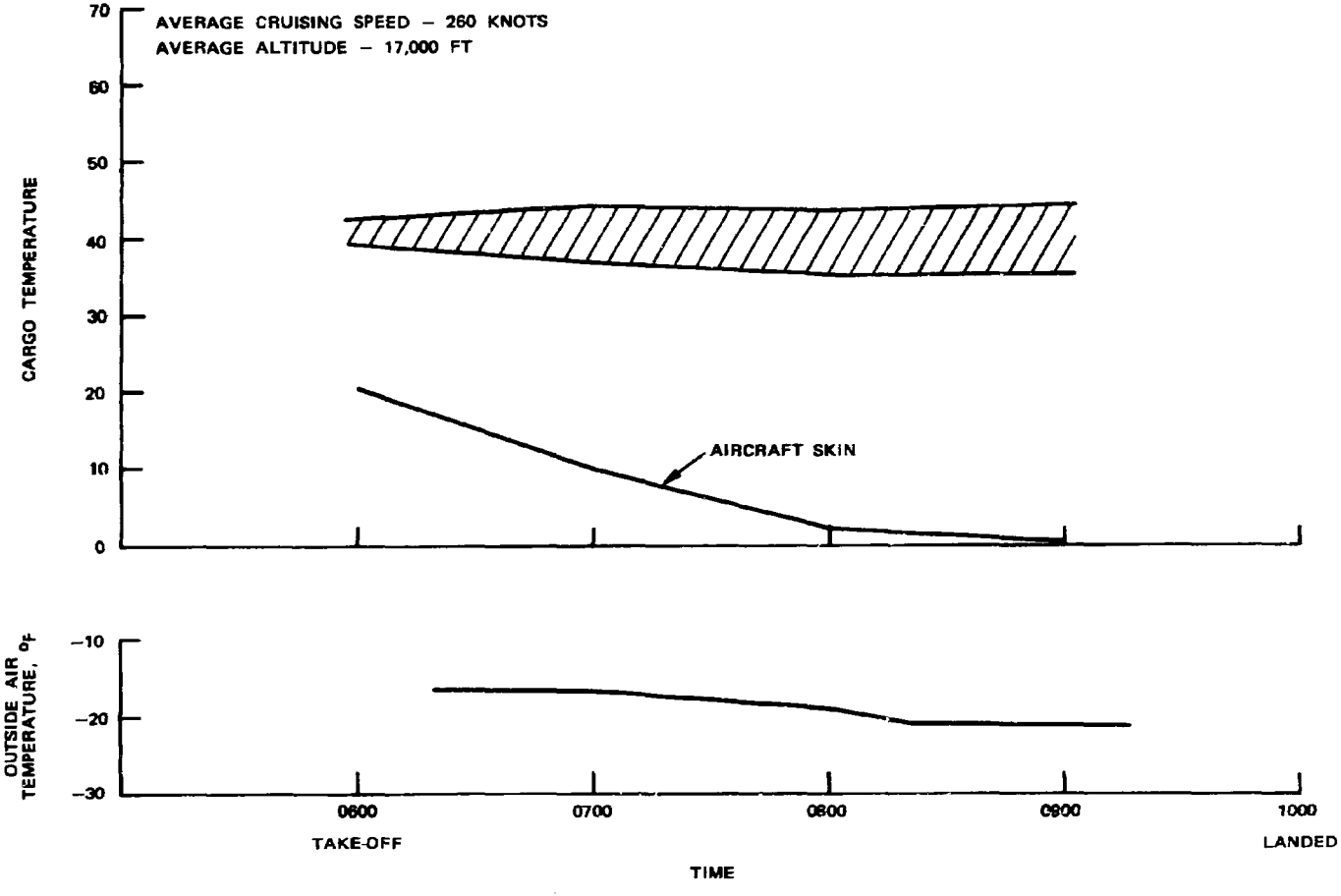

FIG. 13. C-133 Flight 2010, McGuire AFB to Argentia, Newfoundland (1/15/69).

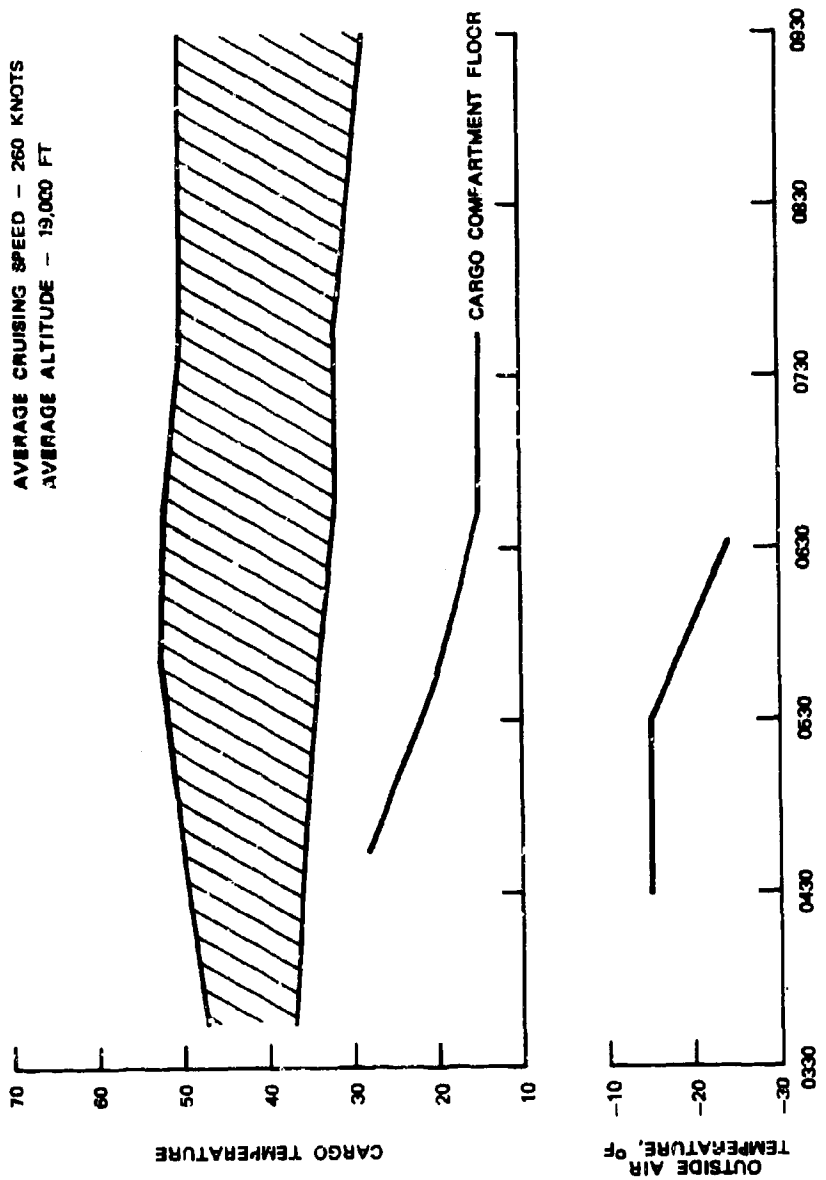

FIG. 14. C-133 Flight 2010, Argentia, Newfoundland to Prestwick, Scotland (1/16/69).

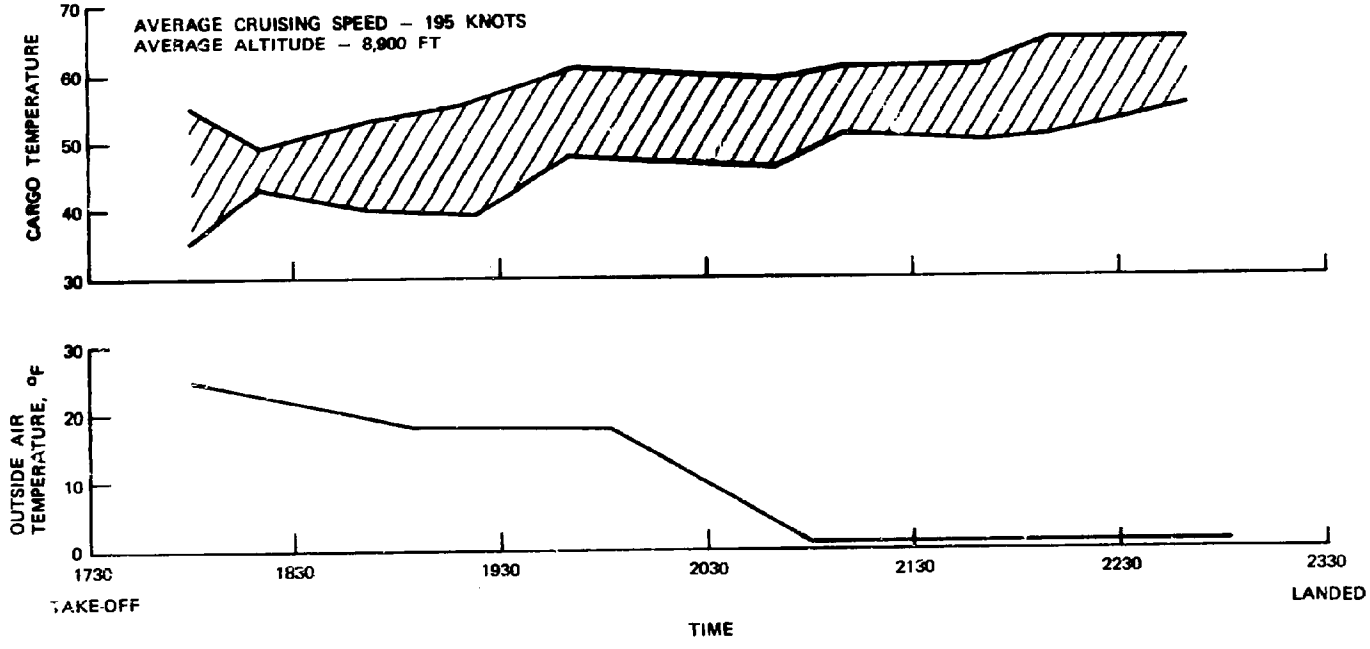

FIG. 15. C-124 Flight 10092, McGuire AFB to Goose Bay, Labrador (1/28/69).

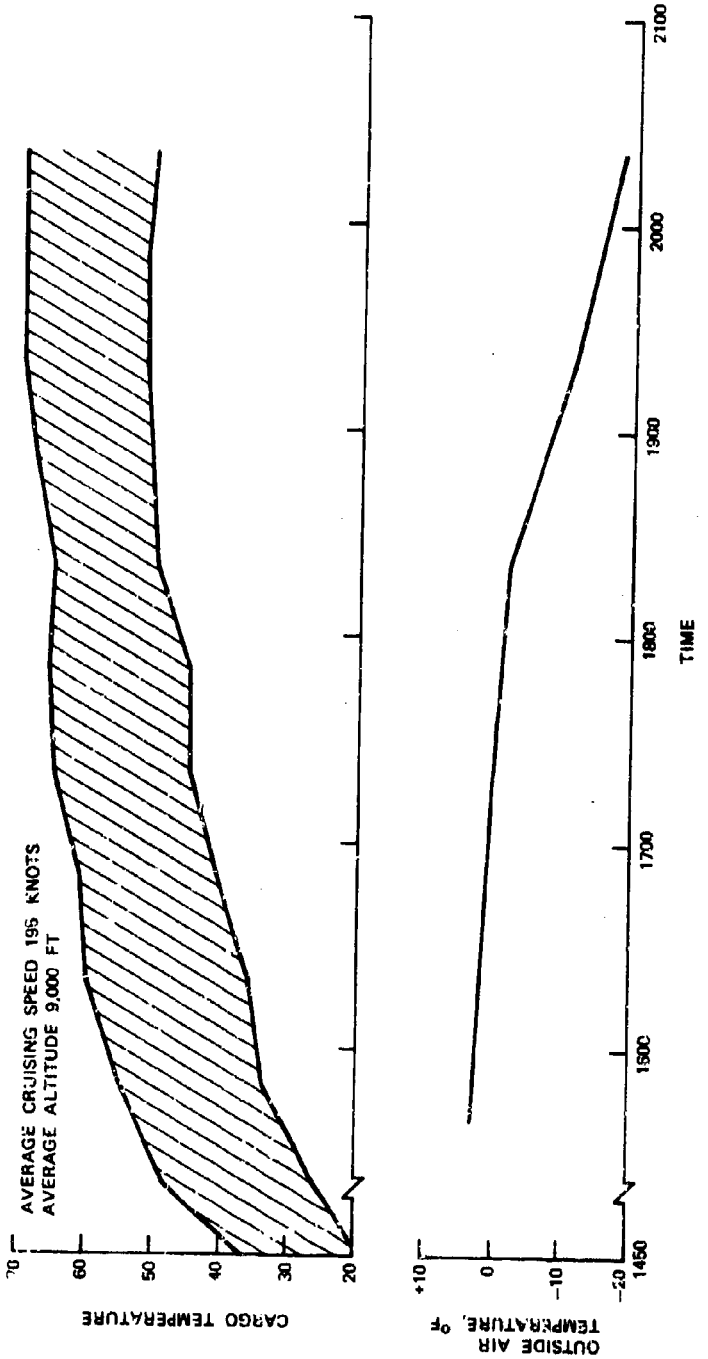

FIG. 16. C-124 Flight 10092, Goose Bay, Labrador to Sonderstrom, Greenland (1/29/69).

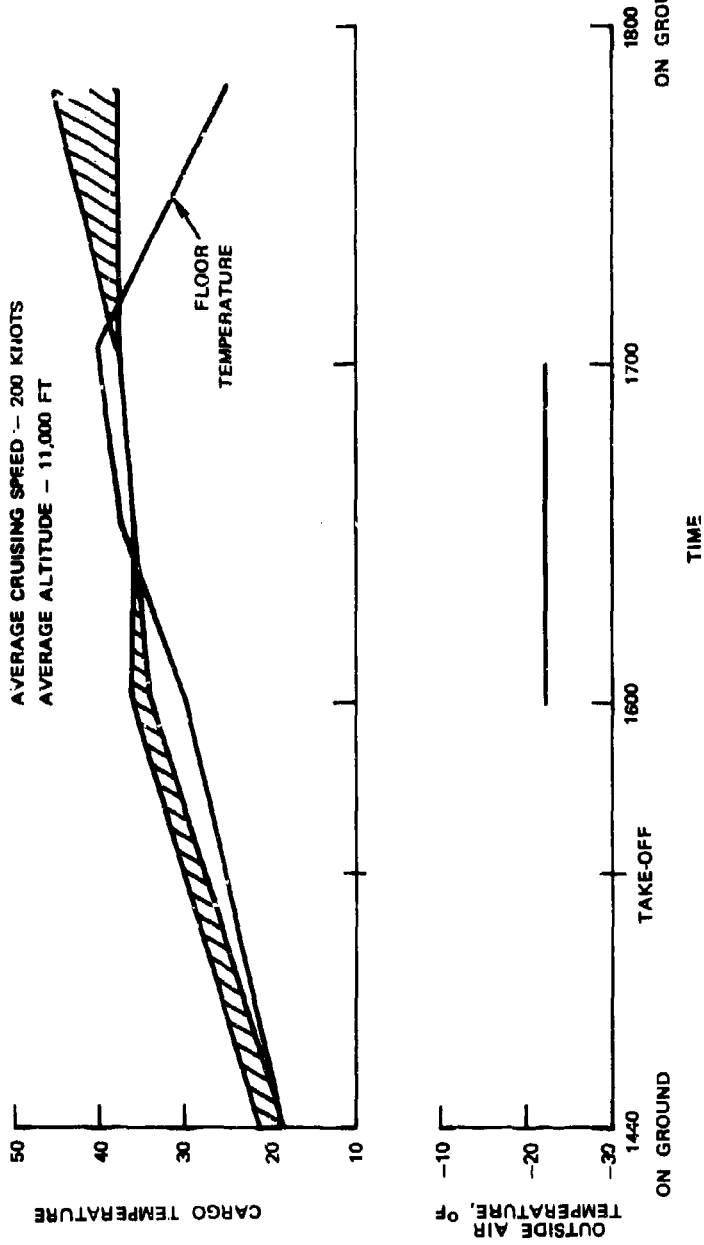

FIG. 17. C-124 Flight 10092, Sonderstrom, Greenland to Kulusuk, Greenland (1/31/69).

The C-124 flight from McGuire AFB to Greenland was interesting in that each leg of the flight had an entirely different cargo configuration. The aircraft was fully loaded to maximum weight while flying the McGuire to Goose Bay leg, and for the other extreme, the Goose Bay to Sonderstrom flight carried a minimal weight load of 5,000 pounds. The Sonderstrom to Kulusuk flight carried a volume loaded cargo of structural antenna parts. The 8,200 pounds of antenna parts were so large they could not be loaded as is normally done through the elevator so the clam shell doors in the nose were opened and the crates of antennas were manhandled on and off the aircraft. Figure 18 shows the C-124 being off-loaded at the remote landing strip in Kulusuk, Greenland.

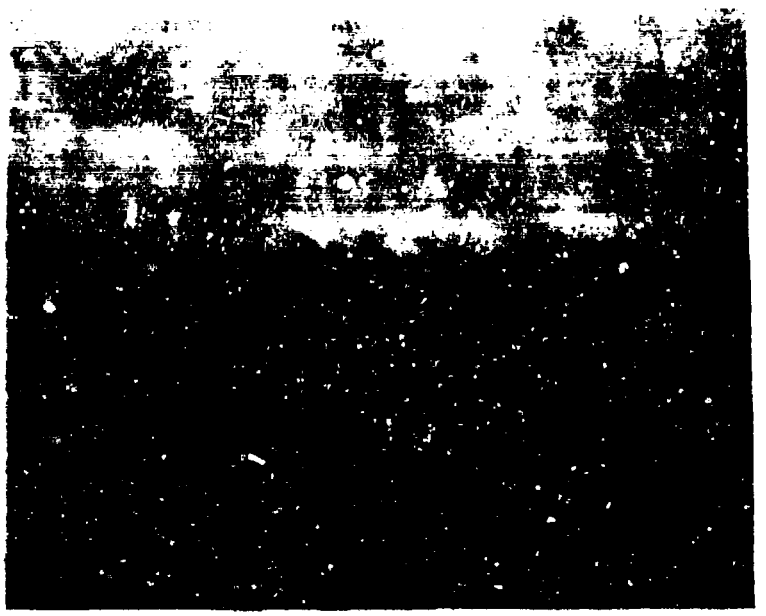

FIG. 18. C-124 Being Off-Loaded in Greenland.

The antenna parts were loaded on the C-124 one day prior to the scheduled takeoff. The aircraft remained on the flight line parking ramp exposed to sub-zero weather conditions. Twelve hours prior to the scheduled takeoff, Herman Nelson heaters were connected by means of 12-inch ducts to each engine and one placed inside the forward hatch of the aircraft. Figure 3 shows the heater hookup to the aircraft.

Arrangements were made between the NWC personnel and the aircraft Commander to shut the heater off or set the temperature control to a minimum in the cargo compartment during two of the flights. One of the flights mentioned was the C-141 S/N 08083 going from McGuire AFB to Rein-Main, Germany. One heater pack was shut off while the other was set to its lowest temperature setting. This condition was maintained for almost the entire flight.

A fact of interest and note in conjunction with extreme high altitude flight of cargos in C-141 aircraft is as follows: The aircraft has two heater-pressure packs. One is for the crew flight deck (2/3) and the cargo compartment (1/3). The other is totally for the cargo compartment. If one heater-pressure pack is lost due to malfunction, then the other is pressed into service to supply pressurization and heat to the crew flight deck and cargo compartment. However, even in this emergency situation, the cargo is still subjected to heating. If both packs are put out of commission, it is emergency procedure to abandon the high altitude situation and fly at an altitude conducive to crew comfort and breathing. Therefore, the cargo will not be subjected to the high altitude cold soak under these circumstances. The NWC personnel made arrangements with the 438 MAC Air Wing to disable one of the two packs and turn the thermostat in the cargo compartment off during a McGuire AFB to Rein-Main, Germany C-141 flight. The results are shown in Fig. 10. Notice that the cargo compartment temperature is still quite mild. On the return flight of the same aircraft that same day, the new crew was given no instructions. Notice the difference in cargo temperature for the return flight as shown in Fig. 11.

The point should be made that much inferred information can be obtained from the pilots' handbooks for the given aircraft. However, this information cannot be treated out of context and accurate cargo soak temperatures theoretically derived. Such interacting relationships as fuel comsumption to achieve altitude with a given load, crew comfort, physical relations of flight, modes of heat transfer, and other extenuating circumstances must be placed in proper context.

Also notice that the outside air temperature during the flights are in close approximation to the extreme values specified for the altitude by MIL-STD-210.

The flight with the C-133 from McGuire to Argentia, Newfoundland was also made with the heater off in the cargo compartment. It is interesting to note that even though the heater was off, the cargo temperature did not drop drastically. The inside skin of the aircraft measured on channel 7 dropped from 20 to 0°F in 3 hours. This illustrates the obvious fact that the large mass of cargo will not readily change from its ambient temperature state and drop to some value approaching the outside air temperature.

CONCLUSIONS

It is indicated in Fig. 10 through 17 that the minimum temperature design situation for air carried cargo is in the neighborhood of 20°F or greater. The inside aluminum skin temperature of the aircraft is indicated to be about 0°F minimum. Therefore, the design minimum temperature for air transported material should be in the range between 0 and 20°F.

It is also concluded that extenuating circumstances dictate that neither the low, slow aircraft or the high flying jet will surpass this envelope enough of the time to be engineeringly significant.

During this measurement series the lowest cargo temperature measured was 19°F even though true outside air temperatures of -82°F were recorded.

Appendix A

INDICATED VERSUS TRUE OUTSIDE AIR TEMPERATURE

Indicated outside air temperature (OAT) is always higher than true OAT during flight because of the temperature rise associated with ram effects on the indicating system. All reference to OAT in this report is in the corrected or true OAT format. This was accomplished by using the plot of Fig. 19 which is a direct copy from the Air Force Flight Manual. This figure, Pg AI-7 of Appendix I of Air Force T.O. 1C-141A-1-1, gives the relationship of indicated OAT versus the true OAT such as would be measured by a man in a balloon with a thermometer.

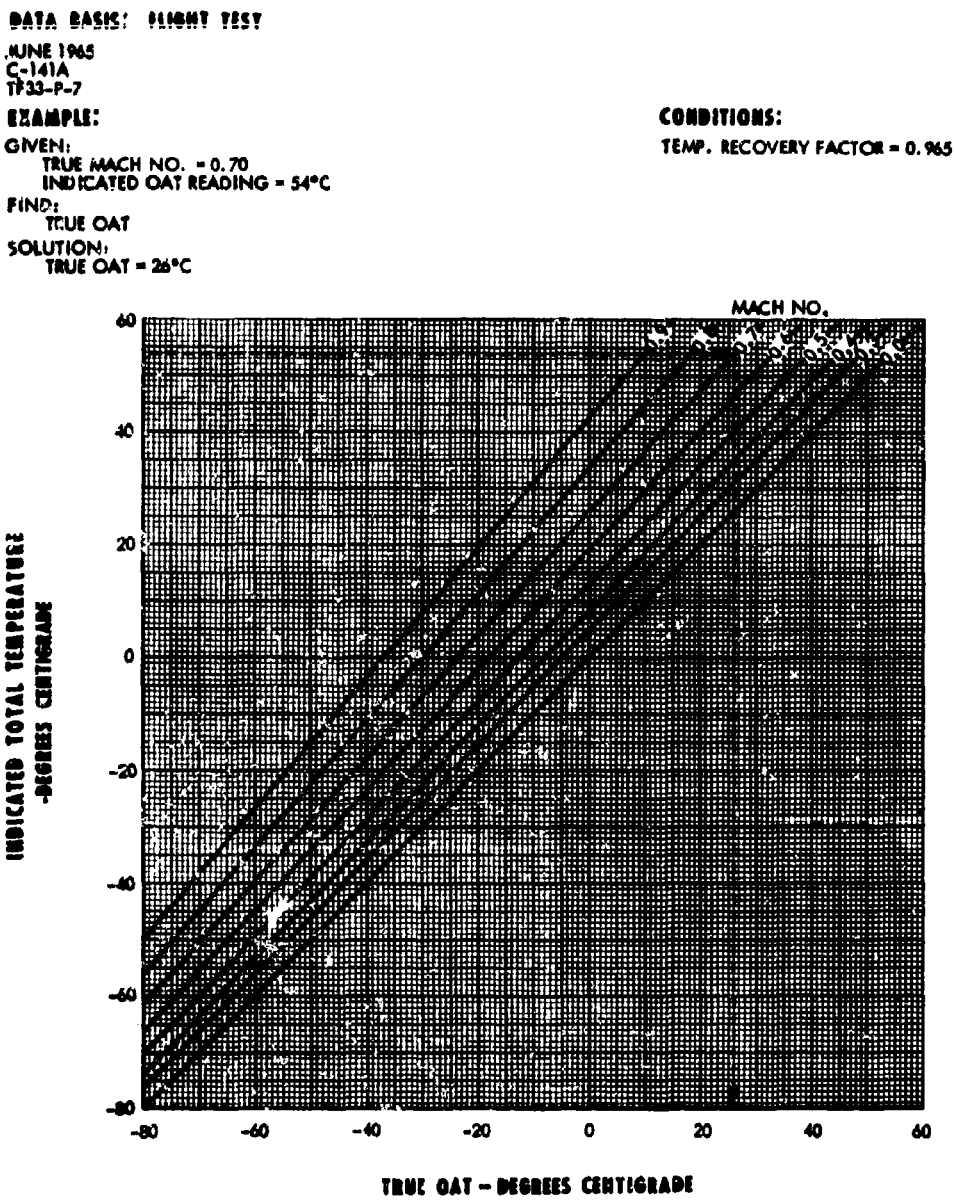

FIG. 19. Indicated Total Temperature Versus True Outside Air Temperature (OAT).

Appendix B
COMPLETE TEMPERATURE LOG OF INSTRUMENTED FLIGHTS

TABLE 2. C-141 Flight 08083, McGuire AFB to Rein-Main,

Time (GMT)	Recorder channels/°F											
	1	2	3	4	5	6	7	8	9	10	11	12
0635	..	..	..	..	50	46	..	48	45	45	45	44
0700	66	52	48	50	52	46	26	50	44	44	44	44
0715	65	51	48	51	52	48	14	50	44	44	44	44
0730	65	52	48	51	52	49	12	50	44	45	45	45
0745	64	52	48	51	51	50	10	50	44	45	45	45
0800	64	52	48	50	50	50	9	50	44	45	45	45
0815	63	51	49	50	50	50	7	50	43	45	46	46
0830	62	51	49	50	50	50	4	50	42	46	46	46
0845	61	52	50	51	51	50	6	50	42	45	46	46
0900	60	52	50	51	51	50	6	50	42	46	46	46
0915	60	52	50	51	51	51	7	50	42	45	46	46
0930	60	52	50	51	50	50	7	50	42	45	46	46
0945	59	51	50	50	50	50	6	50	43	46	47	47
1000	59	51	50	51	50	50	6	49	42	44	46	46
1030	58	50	50	50	49	50	5	49	42	44	46	46
1100	58	50	50	50	49	50	4	49	41	44	46	46
1130	58	50	49	50	48	50	4	48	41	44	46	46
1200	56	48	48	48	46	48	6	47	40	44	46	46
1235	56	48	48	48	46	48	8	47	40	44	46	46
1300*	56	49	49	50	57	48	10	52	40	43	44	44
1315	58	67	53	62	75	54	14	63	47	43	44	44
1330	66	75	54	65	80	51	38	68	56	50	44	44

NOTE: Total flight time: 6 hr 55 min.
Recorder channels 1 through 6 and 8 through 12: Palletized cargo.
Recorder channel 7: Cargo compartment floor.
*Heaters turned on.

C-141 Flight 08083, McGuire AFB to Rein-Main, Germany (1/18/69).

Recorder channels/°F							Outside air temp. °F	Position	Speed, knots	Altitude, ft
6	7	8	9	10	11	12				
46	..	48	45	45	45	44	..	..	..	Take off
46	26	50	44	44	44	44	..	..	..	Climbing
48	14	50	44	44	44	44	-67	4522 N 6208 W	447	33,800
49	12	50	44	45	45	45	..	..	..	..
50	10	50	44	45	45	45	..	..	..	..
50	9	50	44	45	45	45	..	4648 N 5632 W	..	..
50	7	50	43	45	46	46	..	..	..	..
50	4	50	42	46	46	46	..	..	..	..
50	6	50	42	45	46	46	..	..	..	..
50	6	50	42	46	46	46	-69	..	435	37,000
51	7	50	42	45	46	46	..	..	..	..
50	7	50	42	45	46	46	..	..	..	..
50	6	50	43	46	47	47	..	..	..	..
50	6	49	42	44	46	46	-72	4832 N 3549 W	440	37,000
50	5	49	42	44	46	46	..	..	..	..
50	4	49	41	44	46	46	-72	4902 N 1756 W	440	36,700
50	4	48	41	44	46	46	..	..	..	..
48	6	47	40	44	46	46	-67	4901 N 0041 W	448	37,000
48	8	47	40	44	46	46	..	Over Paris	..	..
48	10	52	40	43	44	44	..	..	..	..
54	14	63	47	43	44	44	..	..	..	..
61	38	68	56	50	44	44	..	..	..	On ground

.
nd 8 through 12: Palletized cargo.
artment floor.

TABLE 3. C-141 Flight 08083, Rein-Mein, Germany to McGuire AFB (1/18/69).

Time (GMT)	Recorder channels/°F						Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5	6				
1500	47	45	47	42	44	45	..	..	..	..
1545	47	45	48	42	45	46	..	..	..	..
1600	48	43	50	40	44	47	..	..	..	..
1630	50	44	53	42	46	48	-54	5242 N 0415 E	443	..
1700	50	45	54	42	47	48	..	..	..	..
1730	52	46	54	42	48	48	-54	5626 N 0602 W	447	35,000
1800	53	47	54	43	48	48	..	..	..	..
1830	54	48	54	43	48	48	-69	6038 N 1745 W	447	35,000
1900	54	48	54	43	48	48	..	..	..	..
1930	56	50	56	44	49	50	-58	6048 N 3242 W	447	35,000
2000	56	50	56	45	49	51	..	..	..	..
2030	54	51	53	45	48	48	-82	5240 N 4700 W	435	35,000
2100	54	51	52	44	47	48	..	..	..	..
2130	56	51	54	45	48	50	-56	5525 N 5730 W	443	35,000
2200	56	52	55	46	48	50	..	..	..	..
2230	55	52	54	45	48	49	-76	5100 N 6432 W	444	35,000
2300	55	52	53	45	47	49	..	..	..	..
2330	54	52	52	44	47	48	-76	4638 N 7032 W	442	35,000
2400	54	52	53	45	47	48	..	..	..	..
0030	55	53	54	45	48	50	..	..	..	..
0100	59	52	59	44	48	52	..	..	..	On ground

NOTE: Total flight time: 10 hr.
Recorder channels 1 through 6: Palletized cargo.

TABLE 4. C-141 Flight 40642, Rein-Main, Germany to McGuire AFB (1/22/69).

Time (GMT)	Recorder channels/°F					Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5				
1035	..	..	..	..	..	..	..	..	Take off
1100	50	59	74	75	44	-71	5129 N 0025 E	440	35,000
1200	70	67	76	84	48	-67	5200 N 0450 W	443	35,000
1300	74	68	78	84	52	-71	5300 N 1520 W	435	37,000
1400	74	70	78	85	54	-51	5300 N 2745 W	450	..
1500	74	71	80	85	57	-62	5218 N 3752 W	448	..
1600	74	72	80	82	59	-63	5045 N 5100 W	440	..
1700	71	70	79	83	59	-81	4700 N 6100 W	440	..
1800	72	69	79	85	60	-76	4315 N 6700 W	435	..
1920	70	72	78	76	62	..	..	..	On ground

NOTE: Total flight time: 8 hr 20 min.
Recorder channels 1 through 5: Bullpup motor shipping containers.

TABLE 5. C-133 Flight 2010, McGuire AFB to Argentia, Newfoundland (1/15/69).

Time (GMT)	Recorder channels/°F							Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5	6	7				
0510	..	..	..	..	..	..	..	..	..	..	Take off
0600	42	40	41	39	39	38	20	..	..	..	..
0700	43	44	43	39	37	36	10	-16	4110 N 7000 W	260	17,000
0800	42	42	43	37	36	35	2	-18	4350 N 6605 W	260	17,000
0900	44	44	44	38	37	35	0	-20	4525 N 6260 W	260	17,000
0914	..	..	..	..	..	..	..	-20	4645 N 5710 W	260	17,000
1000	..	..	..	..	..	..	..	..	..	..	On ground

NOTE: Total flight time: 4 hr 50 min.
Recorder channels 1 through 6: Palletized cargo.
Recorder channel 7: Aircraft skin in cargo compartment.

TABLE 6. C-133 Flight 2010, Argentia, Newfoundland to Prestwick, Scotland (1/16/69).

Time (GMT)	Recorder channels/°F							Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5	6	7				
0330	..	..	..	..	..	..	..	..	..	..	Take off
0340	40	47	47	40	37	43	..	..	..	..	..
0440	43	48	50	40	36	43	28	-15	5000 N 4800 W	260	17,000
0540	43	51	52	40	34	41	20	-15	5100 N 4300 W	260	17,000
0640	44	50	52	39	32	41	15	-22	..	260	19,000
0740	43	49	50	37	32	40	15	..	..	..	..
0932	43	48	50	37	28	38	..	..	..	..	On ground

NOTE: Total flight time: 6 hr.
Recorder channels 1 through 6: Palletized cargo.
Recorder channel 7: Aircraft skin in cargo compartment.

TABLE 7. C-124 Flight S/N 21036, McGuire AFB to Goose Bay, Labrador (1/25/69).

Time (GMT)	Recorder channels/°F												Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5	6	7	8	9	10	11	12				
0029	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Take off
0100	45	40	40	40	43	40	53	52	..	50	44	42	..	..	..	..
0115	48	42	42	41	46	42	66	56	..	56	50	55	..	..	..	..
0130	50	44	42	42	49	42	68	61	..	60	54	60	..	..	..	..
0200	52	45	43	43	50	48	70	64	..	64	56	62	+18	4221 N 7100 W	237	9,000
0215	54	46	44	44	52	44	74	66	58	66	60	64	..	..	..	..
0245	56	49	46	47	54	46	77	70	72	70	64	68	..	..	..	..
0300	58	50	46	48	54	47	78	70	62	70	64	68	..	..	..	..
0315	58	50	46	48	54	47	78	71	63	71	66	69	+18	4542 N 6841 W	243	9,000
0330	59	52	47	50	54	48	79	72	64	72	66	70	..	..	..	..
0345	60	53	48	50	54	48	80	73	64	73	68	71	..	..	..	..
0400	62	54	49	52	55	50	81	74	66	72	70	73	+18	..	245	9,100
0415	63	55	50	54	56	50	81	75	66	74	70	74	..	..	..	..
0430	64	56	50	55	56	51	81	76	66	75	71	74	..	..	..	..
0445	64	56	50	56	56	52	81	76	67	76	71	74	..	..	..	..
0500	64	57	51	56	56	52	82	76	67	76	72	75	..	..	..	..
0515	66	58	52	56	56	52	82	76	68	76	72	76	..	..	..	..
0530	66	58	52	58	57	53	83	78	68	77	73	76	..	..	..	..
0545	68	59	52	58	58	55	84	80	71	80	74	80	..	..	..	..
0600	69	61	54	60	60	56	82	77	69	79	74	77	..	..	..	On ground

NOTE: Total flight time: 6 hr.
Recorder channels 1 through 12: Placed in various locations in cargo compartment.

TABLE 8. C-124 Flight S/N 21036, Goose Bay, Labrador to Rein-Main, Germany (1/27/69 - 1/28/69).

Time (GMT)	Recorder channels/°F												Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5	6	7	8	9	10	11	12				
2035	44	44	44	44	44	44	44	44	44	44	44	44	..	..	..	..
2100	50	48	52	57	50	55	..	60	66	70	68	68	..	..	..	Climbing
2115	54	52	58	64	56	62	..	71	68	61	69	70	..	..	..	..
2130	58	52	63	79	59	64	81	79	78	81	78	78	..	..	..	..
2145	64	54	69	76	64	70	86	85	82	86	81	85	..	..	..	..
2200	64	55	70	78	64	69	86	86	82	86	83	86	+23	5350 N 5610 W	235	9,100
2215	65	56	72	78	64	70	87	87	83	87	83	86	..	..	..	..
2230	68	58	73	80	66	71	88	87	85	89	86	89	..	..	..	..
2245	70	59	74	82	70	72	88	87	84	86	83	86	..	..	..	..
2300	72	60	75	81	67	72	85	84	82	84	82	85	..	..	..	..
2315	71	60	74	81	67	71	85	83	82	84	82	85	+24	5415 W 4800 N	230	9,140
2330	72	62	75	82	68	72	86	84	82	85	82	85	..	..	..	..
2345	72	62	76	81	68	70	85	84	82	84	82	85	..	..	..	..
2400	72	63	76	82	68	71	85	84	82	84	82	85	..	..	..	..
0015	73	64	76	82	68	71	85	84	82	84	82	84	..	..	..	..
0030	72	64	75	82	68	70	85	84	82	85	84	85	+23	4000 W 5500 N	232	9,140
0045	73	64	76	82	68	72	84	84	82	85	83	85	..	..	..	..
0100	74	65	76	82	70	71	85	84	82	84	83	85	..	..	..	..
0115	73	64	76	81	70	70	84	84	82	84	82	84	..	..	..	..
0130	73	64	76	80	72	69	83	83	82	84	82	85	+16	3400 W 5430 N	210	9,140
0145	77	68	78	82	69	70	84	85	82	84	83	85	..	..	..	..
0200	77	67	77	82	68	70	85	85	83	84	83	86	..	..	..	..
0215	77	68	77	82	68	71	84	86	83	84	83	86	..	..	..	..
0230	78	70	78	83	68	71	85	86	84	85	84	85	..	..	..	..
0245	78	70	78	83	68	71	86	86	84	85	84	85	+10	2600 W 5350 N	200	9,150
0300	77	70	77	82	68	70	85	86	84	85	84	86	..	..	..	..
0315	76	70	77	81	71	70	85	86	83	86	84	86	..	..	..	..
0330	75	70	77	80	71	70	86	85	84	86	84	86	..	..	..	..

0015	73	64	76	82	68	71	85	84	82	84	82	84	..	..	..	..
0030	72	64	75	82	68	70	85	84	82	85	84	85	+23	4000 W 5500 N	232	9,140
0045	73	64	76	82	68	72	84	84	82	85	83	85	..	..	..	..
0100	74	65	76	82	70	71	85	84	82	84	83	85	..	..	..	..
0115	73	64	76	81	70	70	84	84	82	84	82	84	..	..	..	..
0130	73	64	76	80	72	69	83	83	82	84	82	85	+16	3400 W 5430 N	210	9,140
0145	77	68	78	82	69	70	84	85	82	84	83	85	..	..	..	..
0200	77	67	77	82	68	70	85	85	83	84	83	86	..	..	..	..
0215	77	68	77	82	68	71	84	86	83	84	83	86	..	..	..	..
0230	78	70	78	83	68	71	85	86	84	85	84	85	..	..	..	..
0245	78	70	78	83	68	71	86	86	84	85	84	85	+10	2600 W 5350 N	200	9,150
0300	77	70	77	82	68	70	85	86	84	85	84	86	..	..	..	..
0315	76	70	77	81	71	70	85	86	83	86	84	86	..	..	..	..
0330	75	70	77	80	71	70	86	85	84	86	84	86	..	..	..	..
0345	75	72	78	80	70	71	86	86	84	86	84	87	..	..	..	..
0400	74	71	78	78	68	70	84	84	83	85	83	86	+14	1930 W	210	9,140
0415	74	71	76	78	71	70	84	84	83	84	82	85	..	..	..	..
0430	73	71	76	78	70	70	84	84	83	85	83	85	..	..	..	..
0445	73	71	76	79	70	70	85	85	83	85	82	85	..	..	..	..
0500	76	72	77	79	71	70	84	84	83	85	83	86	+8	..	200	9,150
0515	74	72	77	78	73	69	86	84	82	84	83	85	..	..	..	..
0530	73	71	76	78	74	69	84	84	82	85	83	85	..	..	..	..
0545	74	72	77	78	73	70	84	84	83	85	84	86	..	..	..	..
0600	74	72	77	78	73	70	84	84	83	85	84	86	..	..	..	..
0615	74	72	78	79	69	70	85	85	83	86	84	86	..	..	..	..
0630	74	72	78	78	68	70	84	84	82	86	84	85	..	..	..	..
0645	74	73	77	78	68	70	84	84	83	84	83	85	..	..	..	..
0700	73	72	77	78	68	70	84	84	82	84	83	86	..	..	..	..
0715	72	72	77	78	68	70	85	85	82	84	82	85	..	..	..	..
0730	73	72	77	78	69	71	85	84	83	84	84	85	..	..	..	..
0745	72	72	76	78	69	70	84	84	83	84	83	85	..	..	..	..
0800	72	72	76	78	68	71	84	84	83	85	83	84	..	..	..	..
0815	74	74	76	78	70	72	85	84	83	85	83	86	..	..	..	..
0830	74	74	76	78	70	71	84	83	83	85	83	86	..	..	..	..
0845	72	72	75	75	77	82	94	78	80	85	86	86	..	Rein-Main	..	On ground

NOTE: Total flight time: 12 hr 10 min.
Recorder channels 1 through 12: Placed in various locations in cargo compartment.

TABLE 9. C-124 Flight S/N 21036, Rein-Main, Germany to Prestwick, Scotland (1/30/69).

Time (GMT)	Recorder channels/°F												Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5	6	7	8	9	10	11	12				
0600	45	40	42	46	50	47	43	43	47	50	50	50	..	..	..	On ground
0700	50	44	48	52	66	52	48	61	56	61	58	59	..	..	..	..
0715	52	43	50	54	68	54	49	64	58	64	61	61	..	..	..	..
0730	53	42	51	54	68	55	50	66	60	66	63	64	..	..	..	..
0745	55	42	53	56	70	57	52	68	63	70	66	66	..	..	..	..
0800	56	43	54	58	74	58	54	70	65	71	68	68	..	..	..	..
0815	58	45	57	60	77	61	57	74	68	74	70	71	..	..	..	..
0830	58	45	57	60	78	61	57	74	68	74	70	71	..	..	..	..
0845	61	48	60	63	80	63	57	76	71	78	74	74	..	..	..	..
0900	63	50	63	64	65	66	52	70	66	74	69	71	..	..	..	..
0915	64	50	64	64	76	64	63	63	70	74	73	73	..	..	..	..
0930	64	51	64	65	82	66	64	66	79	81	78	78	..	..	..	..
0945	65	52	66	66	73	68	66	78	74	79	76	76	..	..	..	..
1000	66	53	67	67	75	68	66	78	74	80	77	77	..	..	..	..
1015	64	48	62	63	74	63	62	66	71	76	74	73	..	..	..	..
1030	62	49	64	64	67	65	64	70	71	76	74	72	..	..	..	..
1045	62	48	64	64	72	64	64	73	72	76	75	74	..	..	..	..
1100	62	46	64	64	72	64	65	74	73	78	76	75	..	..	..	..
1115	64	48	65	66	68	68	66	72	74	75	70	72	..	..	..	..
1130	69	66	60	66	82	66	66	65	65	66	66	68	..	..	..	On ground

NOTE: Total flight time: 5 hr 30 min.
Recorder channels 1 through 12: Placed in various locations in cargo compartment.

TABLE 10. C-124 Flight S/N 21036, Prestwick,

Time (GMT)	Recorder channels/°F									
	1	2	3	4	5	6	7	8	9	10
1450	46	48	44	47	54	51	64	..	55	53
1515	44	51	46	50	57	54	50	..	57	57
1530	44	53	46	52	59	56	51	66	61	62
1545	44	54	46	53	60	57	52	67	64	65
1600	44	55	47	54	61	58	53	70	67	67
1615	44	56	48	55	61	59	53	70	69	69
1630	45	56	48	56	62	60	54	72	70	70
1645	46	59	49	58	64	64	56	74	74	73
1700	47	60	50	58	64	64	58	75	75	75
1715	48	61	51	67	64	63	58	74	76	76
1730	48	61	52	64	64	63	59	74	76	76
1745	50	61	52	64	64	62	59	72	75	74
1800	49	60	52	64	64	62	59	70	74	73
1815	50	60	53	63	64	62	58	70	73	72
1830	50	60	54	60	64	62	58	67	74	73
1845	51	59	54	62	62	60	58	68	72	70
1900	50	60	54	62	66	60	60	73	74	72
1915	52	62	54	78	92	64	68	102	86	82
1930	56	65	54	62	78	63	64	75	87	83
1945	56	67	54	77	98	64	70	107	94	88
2000	60	72	56	66	86	67	70	82	96	92
2015	56	70	56	74	82	68	68	84	92	89
2030	56	71	57	75	81	69	68	85	90	88
2045	56	71	58	72	80	70	69	83	88	86
2100	56	70	58	72	87	69	69	92	89	86
2115	57	72	58	74	96	68	72	106	94	90
2130	58	72	60	69	82	70	68	82	91	88
2205	59	72	61	78	83	79	91	90	84	92

NOTE: Total flight time: 7 hr 15 min.
Recorder channels 1 through 12: Placed in various locations in ca

0. C-124 Flight S/N 21036, Prestwick, Scotland to Azores (1/30/69).

Recorder channels/°F								Outside air temp, °F	Position	Speed, knots	Altitude, ft
5	6	7	8	9	10	11	12				
4	51	64	..	55	53	58	56	..	..	..	..
7	54	50	..	57	57	62	61	..	..	..	..
9	56	51	66	61	62	66	66	..	..	..	..
0	57	52	67	64	65	69	70	..	..	..	..
1	58	53	70	67	67	72	72	+23	..	170	8,100
1	59	53	70	69	69	74	75	..	..	..	..
2	60	54	72	70	70	75	76	..	..	..	..
4	64	56	74	74	73	79	80	..	..	..	..
4	64	58	75	75	75	80	81	..	..	..	..
4	63	58	74	76	76	80	82	..	..	..	..
4	63	59	74	76	76	80	81	..	..	..	..
4	62	59	72	75	74	79	80	..	..	..	..
4	62	59	70	74	73	77	78	..	..	..	..
4	62	58	70	73	72	76	77	..	..	..	..
4	62	58	67	74	73	76	76	..	..	..	..
2	60	58	68	72	70	75	76	..	..	..	..
6	60	60	73	74	72	79	90	+27	..	195	8,100
2	64	68	102	86	82	93	106	..	..	..	..
8	63	64	75	87	83	92	98	..	..	..	..
8	64	70	107	94	88	100	119	..	..	..	..
6	67	70	82	96	92	100	97	..	..	..	..
2	68	68	84	92	89	96	92	..	..	..	..
1	69	68	85	90	88	95	92	..	..	..	..
0	70	69	83	88	86	92	90	..	..	..	..
7	69	69	92	89	86	94	102	..	..	..	..
6	68	72	106	94	90	100	108	..	..	..	..
2	70	68	82	91	88	96	91	..	..	..	..
3	79	91	90	84	92	106	98	..	..	..	End flight

5 min.
h 12: Placed in various locations in cargo compartment.

TABLE 11. C-124 Flight S/N 21036, Azores to Dover, Delaware (2/1/69).

Time (GMT)	Recorder channels/°F												Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5	6	7	8	9	10	11	12				
1130	58	58	58	57	58	58	58	58	58	58	60	58	..	Lajes	..	On ground
1215	60	61	58	59	59	59	75	63	60	60	64	67	..	..	..	Start engines
1245	59	62	59	59	60	60	59	62	62	62	64	62	..	..	..	Airborne
1300	58	63	60	59	60	60	60	65	63	64	64	62	..	..	..	..
1315	59	64	60	58	61	60	60	66	70	66	64	63	+28	39 N 28 W	213	8,150
1330	60	68	62	60	62	62	62	70	71	70	64	65	..	..	..	..
1345	60	68	62	60	63	62	62	71	72	70	64	65	..	..	..	..
1400	61	70	62	60	64	62	63	72	67	72	65	66	..	..	..	..
1415	62	71	62	61	64	64	64	72	68	72	64	67	+23	4130 N 3300 W	218	8,100
1430	63	73	64	62	66	64	65	74	69	74	66	68	..	..	..	..
1445	64	74	64	62	66	65	66	76	71	75	66	69	..	..	..	..
1500	64	74	64	63	67	66	66	74	70	74	65	68	..	..	..	..
1515	64	74	63	63	68	66	66	76	73	75	66	70	..	..	..	..
1530	65	75	63	63	68	67	67	77	73	76	66	70	+26	4215 N 3800 W	212	8,100
1545	66	76	64	64	69	68	88	78	74	76	67	71	..	..	..	..
1600	67	76	63	64	69	67	68	77	73	76	66	70	..	..	..	..
1615	68	77	64	64	70	68	68	78	75	77	67	82	..	..	..	..
1630	68	77	64	65	71	69	69	78	75	78	68	72	+25	4250 N 4330 W	200	8,100
1645	68	77	64	65	70	68	69	78	76	78	68	72	..	..	..	..
1700	67	76	64	65	70	69	70	78	75	77	68	72	..	..	..	..
1715	67	76	63	65	70	68	70	78	76	78	68	72	..	..	..	..
1730	67	76	62	65	70	69	70	78	75	77	68	72	+26	4300 N 4330 W	196	8,100
1745	67	76	62	64	70	68	69	78	74	76	67	72	..	..	..	..

1545	66	76	64	64	69	68	88	78	74	76	67	71	..	..	..	..
1600	67	76	63	64	69	67	68	77	73	76	66	70	..	..	..	..
1615	68	77	64	64	70	68	68	78	75	77	67	82	..	..	..	..
1630	68	77	64	65	71	69	69	78	75	78	68	72	+25	4250 N 4330 W	200	8,100
1645	68	77	64	65	70	68	69	78	76	78	68	72	..	..	..	..
1700	67	76	64	65	70	69	70	78	75	77	68	72	..	..	..	..
1715	67	76	63	65	70	68	70	78	76	78	68	72	..	..	..	..
1730	67	76	62	65	70	69	70	78	75	77	68	72	+26	4300 N 4330 W	196	8,100
1745	67	76	62	64	70	68	69	78	74	76	67	72	..	..	..	..
1800	67	76	62	64	69	69	69	77	74	76	67	72	..	..	..	..
1815	68	77	63	65	69	70	70	78	75	77	68	73	..	..	..	..
1830	68	76	62	64	70	69	69	78	75	77	67	72	+25	4300 N 5300 W	180	8,000
1845	68	76	62	64	70	68	69	78	75	77	68	73	..	..	..	..
1900	68	77	62	65	70	70	70	78	75	77	68	73	..	..	..	..
1915	67	76	60	64	68	68	68	78	75	77	67	72	..	..	..	..
1930	68	78	61	65	70	70	70	79	76	78	68	73	+25	4300 N 5600 W	176	8,000
1945	68	78	61	65	70	70	70	79	76	78	68	74	..	..	..	..
2000	69	78	60	66	71	70	70	79	76	78	78	74	..	..	..	..
2015	70	79	60	64	72	70	70	79	77	78	68	74	..	..	..	..
2030	68	78	60	66	72	70	70	79	76	78	68	74	..	..	..	..
2045	68	78	61	66	72	70	71	80	77	79	69	74	..	..	..	..
2100	69	79	61	66	71	70	71	78	77	78	68	75	..	..	..	..
2115	68	78	61	67	72	71	72	79	78	79	69	75	..	..	..	..
2130	70	80	62	68	73	71	73	80	79	80	70	76	+23	4210 N 6410 W	180	8,000
2145	68	77	60	66	71	70	71	78	76	77	68	75	..	..	..	..
2200	68	77	61	66	71	70	72	78	77	78	69	75	..	..	..	..
2215	68	78	61	66	71	70	72	79	77	78	69	75	..	..	..	..
2230	68	78	61	66	72	70	74	79	77	78	70	76	+25	4117 N 4010 W	190	8,000
2245	69	78	61	66	71	70	74	78	78	78	69	75	..	..	..	..
2300	69	78	62	66	71	71	74	80	78	79	70	76	..	..	..	..
2315	69	78	63	66	71	71	75	80	78	80	70	76	..	..	..	..
2330	69	78	62	66	71	71	74	80	78	79	69	75	..	..	..	..
2345	69	78	60	66	71	70	74	80	78	79	70	76	..	..	..	..

NOTE: Total flight time: 12 hr 15 min.
Recorder channels 1 through 12: Placed in various locations in cargo compartment.

TABLE 12. C-124 Flight 10092, McGuire AFB to Goose Bay, Labrador (1/28/69).

Time (GMT)	Recorder channels/°F						Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5	6				
1730	..	..	..	..	..	..	..	..	..	Take off
1750	35	55	35	35	50	40	..	..	150	..
1815	43	49	45	44	48	43	25	4055 N 7219 W	195	..
1845	40	53	40	40	50	45	..	..	..	..
1915	41	40	45	45	55	49	18	4362 N 7037 W	195	9,000
1945	48	61	48	48	55	51	..	..	..	..
2015	49	60	47	47	56	54	18	4515 N 6830 W	195	8,900
2045	46	59	50	48	56	53	..	..	..	..
2115	51	61	52	50	60	50	2	..	190	9,000
2145	50	61	54	50	59	49	3	..	..	..
2215	55	65	55	52	61	51	..	5210 N 6315 W	195	9,000
2245	55	65	58	55	64	55	2	5220 N 6315 W	195	8,800
2350	..	..	..	..	..	..	..	..	..	On ground

NOTE: Total flight time: 6 hr 20 min.
Recorder channels 1 through 6: Palletized cargo.

TABLE 13. C-124 Flight 10092, Goose Bay, Labrador to Sonderstrom, Greenland (1/29/69).

Time (GMT)	Recorder channels/°F						Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4	5	6				
1450	19	25	21	35	19	37	..	..	..	Take off
1520	26	36	30	38	31	48	..	..	..	..
1550	36	40	39	50	34	55	3	5510 N 6010 W	195	..
1620	40	46	45	54	36	60	..	..	..	..
1650	45	49	47	58	41	61	..	..	..	..
1720	50	50	50	60	45	65	0	5880 N 5880 W	197	9,000
1750	54	55	51	62	45	66	..	..	..	..
1820	55	55	55	63	50	65	-2	6140 N 5630 W	197	9,000
1850	55	55	55	63	51	69	..	..	..	..
1920	54	55	54	65	52	70	-11	6500 N 5505 W	191	9,000
1950	60	55	56	65	52	70	-18	..	..	..
2015	61	56	58	65	51	70	..	..	190	..
2025	..	..	..	..	..	..	..	..	..	On ground

NOTE: Total flight time: 5 hr 35 min.
Recorder channels 1 through 6: Palletized cargo.

TABLE 14. C-124 Flight 10092, Sonderstrom, Greenland to Kulusuk, Greenland (1/31/69).

Time (GMT)	Recorder channels/°F				Outside air temp, °F	Position	Speed, knots	Altitude, ft
	1	2	3	4				
1440	21	19	25	19	..	..	..	On ground
1510	..	..	..	..	..	..	..	Take off
1600	33	35	30	36	-22	..	200	..
1630	35	35	36	36	-22	..	200	11,000
1700	36	36	39	40	-22	..	195	11,000
1755	44	36	24	40	..	..	..	On ground

NOTE: Aircraft loaded 24 hours before takeoff and remained outside on flight line in -20°F weather. Heater was placed in forward hatch 12 hours prior to takeoff.
Recorder channels 1 and 2: Skin measurements of structural antenna parts.
Recorder channel 3: Compartment floor temperature.
Recorder channel 4: Compartment air temperature.

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13. ABSTRACT

Winter flights of MAC aircraft were instrumented to determine the temperatures and temperature profiles to be expected in material during air transport. Flights in 21st Air Force C-141, C-124, and C-133 aircraft from the United States to Greenland and Europe during January are reported herein.

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